INFLUENCE OF WOOD BASIC DENSITY ON *Acacia melanoxylon* KRAFT PROCESS

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Abstract

Wood density is a complex physical property related to the anatomical structure and the chemical composition of wood and one of the most important wood quality factors. Sampling was based on a total of 20 trees from four sites in Portugal that were harvested at a sawmill diameter class of 40 cm and wood discs taken at different height levels from the base to the top of the tree.

The mean basic density of the *Acacia melanoxylon* trees measured at 5% height level (near breast height level) was 516 kg/m^3 with a 34 kg/m^3 standard deviation. The within-tree axial variation of density was of small magnitude, but showing higher values at the stem base and top. Site had no influence on the basic density of the wood. Overall the between tree variation of density was small possibly linked to the narrow genetic diversity of this introduced exotic species. In the Kraft process we can observe variability between stands and an increase of the pulp yield, and fiber width and length with the higher level in the tree. The wood basic density is well correlated with the ISO brightness and well correlated in inverse order with the pulp Yield and fiber width and length. The kappa number don't present a great variation with the wood basic density.

Keywords: *Acacia melanoxylon*, basic density, fiber, kappa number, industrial utilization

I. INTRODUCTION

Acacia is a large woody genus of leguminoseae-mimosoideae species occurring naturally in arid areas in Australia, Asia, Africa, and tropical America. In Portugal *Acacia* spp. were introduced through plantations in the dry and poor sandy soils along the coast in the beginning of the XX century. The country has good ecological conditions for the development of some of the species, and there are nowadays several spontaneous stands dispersed through natural dissemination in all the territory. Their control as an alien invader species by application of chemicals and mechanical removal has not shown enough efficiency.

Acacia melanoxylon (R. Br.) (blackwood) is one of the main wattle species that have disseminated in Portugal, and one of the most important for industrial utilization since it is a valuable timber tree. The potential of *Acacia melanoxylon* as pulpwood has been studied recently (Santos *et al.* 2005).

Wood density is a complex physical property related to the anatomical structure and the chemical composition of wood that responds to genetic, environmental and physiological influences. Density is related to most of the resistance properties of timber as well as to many aspects of wood processing, i.e. chipping, transport, pulp yield, and paper quality (Balodis 1980).

The aim of this study was to investigate the variation of basic density within and between trees of this species in different sites in Portugal, using this information as a prospective tool for an industrial utilization of this species.

II. EXPERIMENTAL

The wood samples originated from *Acacia melanoxylon* (R. Br.) trees were harvested from four different sites in Portugal: Camarido National Forest, at the mouth of Minho river, Caminha; Forest Perimeter of Ovar Dunes, Ovar; Forest Perimeter of Rebordões Santa Maria, Ponte de Lima; Forest Perimeter of Crasto, Viseu**.** These are state-owned stands, un-evenaged and mixed with *Pinus pinaster* Aiton. The stands are conducted in high forestry and selective harvest is made for a sawmill diameter above 40 cm corresponding to an age of revolution of about 50 years.

The trees used in this study were harvested at the end of rotation for timber production corresponding to a class diameter at 1.3 m of 40 cm and five trees were randomly selected in each site. Diameter at 1.3 m height (DBH) was determined as the mean of two cross-diameters. After felling, measurement was made of tree total height and of the commercial height corresponding to the stem up to a 7cm diameter (top).

Six discs were cut from each tree at different height levels along the stem: at the base, at 5%, 15%, 35% and 65% of total tree height and at the top. The top was located at approximately 80% of total tree height. The crown

(indicated by the first living branch) started on average at 38% of stem height (range 9% to 59%). The 5% height level is a near to breast height level, comprehending tree heights between 1.2 to 1.8 m.
Basic density of the samples was determined using the water displacement method (TAPPI T 258 om-94). The chips from each wood disc were carefully homogenized and 100-250g aliquots used for determination.
The wood chips were submitted to the conventional kraft cooking process under the following reaction conditions: active alkali charge = 21.3% (as NaOH); sulfidity index= 30%; liquor/wood ratio = 4/1; time to temperature = 90min; time at temperature (160 ºC) = 90min. Experiments were carried out with 25-g o.d. of wood in a thermostatic oil bath. The cooked chips were disintegrated, washed, and screened on a L&W screen 0.3mm slot wide. The yields pulps, kappa number and ISO Brightness of pulps were determined according to the standard methods.
ANOVA and mean difference tests (Duncan's) were made to assess significant differences for different variation sources.

III. RESULTS AND DISCUSSION

Variation of basic density

The overall mean basic density observed in that study was 529 kg/m^3 ranging from 432 to 658 kg/m^3 and 50% of the studied samples had densities between 500 and 540 kg/m^3. Considering basic density measured only at the 5% height level (near breast height level), the values ranged 454 to 582 kg/m^3 with an average of 516 kg/m^3 and a 34 kg/m^3 standard deviation.
The comparison with basic density values found in the literature for *Acacia melanoxylon* showed similar mean values (Ananias, 1989; Llic, 2000).
The analysis of variance used the linear model with the site and the tree height level as variation factors. The height level in the tree was a very significant factor of variation of wood density, although explaining only 8.3% of the total variation while site showed no statistically significant influence on the variation of density. Most of the variation was included in the residue (91.7%) and refers to the between-tree variability, and other factors not considered.
The wood basic density varied within the tree from the base to the top (Fig. 1). The mean density was higher at the base (536 kg/m^3), decreasing and remaining constant at 522 kg/m^3 in the 5-65% height level stem region, and increasing to the top to 559 kg/m^3. However, statistical analysis showed that there were only two homogeneous groups, one including the base, top and 65% levels and the other the base, 5, 15, 35 and 65% levels.

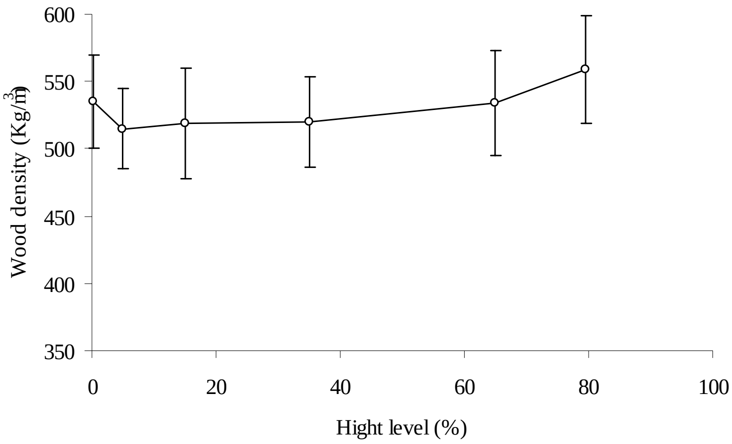

Figure 1. Variation of wood density with the height level.

In hardwoods there is not a defined standard of axial variation of the density, such as it is the case of softwoods with a reduction in density with height (Downes *et al*. 1997), and the variation depends of the species, *i.e.* in eucalypts the interaction between the radial and longitudinal variation allows density to remain constant or increase with height (Hillis and Brown, 1984). The upper part of the stem is under the influence of the crown, and the base is under the influence of the root system resulting that the less impacted positions are in the medium part of the stem, *i.e.* between 25% and 50% of the total tree height (Goulart *et al*. 2003).
There was no influence of site in the variation of basic density and the between tree variation in each site was rather small, corresponding to coefficients of variation of the mean below 7%. A small genetic variability between the trees due to a narrow genetic basis of the initial population may explain the homogeneity of wood density.

Characterization of the Kraft pulps

The results presented in Table 1, show the means and standard deviation for pulp yield, kappa number, ISO Brightness and morphological properties (fibre width and length weight weighted in length) of pulp, of the 85 wood samples. The overall mean pulp yield was 50.5% ranging from 46.5% to 58.2%. The higher pulp yield were observed for the Ovar stand maybe caused for a different wood chemical composition improved by different soil and climate conditions. In fact the variance analysis shows that the site was a significant factor to explain the total variance (20%).

The lower pulp yield were observed for the higher height levels because in that case the wood have a strong influence of the crown tree and have a great percentage of juvenile wood with a higher percentage of lignin content. For the lower height levels (bottom and 5%) we observed too lower values now caused by the possibility of appear reaction wood on the bottom and the effect of the age tree with more extractives, are more significant. Moreover, that observed differences the level three only explain 6.6% of the total variance and the residual is too higher (73.3%) explained by the higher variability of the raw material.

The variation of kappa number was smaller because the condition was adjusted to have a Kappa number near to 14, and the data obtained for the sites are in accordance with the observed for pulp yield, i.e., lower Kappa number for the Ovar stand and higher for the Ponte de Lima and Viseu.

The variance analysis show that the selected factor doesn't have a significant contribution to explain the total variation, moreover the residual explain 78.8% of the total variance caused by the previously explained.

Table 1. Means values and standard deviation of pulp *A. melanoxylon* properties

Site	Level	Basic density (kg/m^3) (DENS)	ISO Brightness (B)	kappa number (IK)	Weighted in lenght (mm) (LL)	Width (mm) (W)	Yield (%) (Y)
Caminha	65	524±17	32.2±6.4	12.7±0.6	0.714±0.021	17.2±0.8	52.1±2.7
	35	504±30	28.8±1.7	13.5±0.4	0.738±0.023	17.7±1.2	51.7±0.9
	15	543±38	26.7±3.5	13.0±0.5	0.751±0.062	19.1±1.4	50.8±1.5
	5	510±36	27.0±3.4	13.4±1.1	0.714±0.042	19.4±2.3	50.3±0.8
	B	529±29	19.9±0.6	14.4±1.6	0.706±0.022	19.6±1.2	50.5±2.4
Ovar	65	515±15	34.4±10.4	13.6±3.4	0.805±0.071	17.7±0.5	52.3±2.4
	35	530±40	26.4±7.3	13.3±1.6	0.776±0.063	19.3±1.3	52.9±3.0
	15	493±35	30.0±5.2	13.6±1.9	0.744±0.029	20.4±2.1	52.2±1.4
	5	502±27	29.5±0.4	14.1±0.1	0.791±0.054	17.2±1.4	49.6±1.3
	B	548±52	24.5±4.9	11.7±1.2	0.727±0.029	20.8±0.7	51.7±1.3
Ponte de Lima	T	569±50	31.1±5.8	15.5±1.1	0.716±0.061	17.4±0.4	47.4±1.6
	65	546±61	26.3±4.2	14.6±0.7	0.674±0.013	19.1±1.0	49.1±1.9
	35	535±35	28.4±4.9	14.0±1.5	0.721±0.027	17.7±1.0	50.0±1.7
	15	522±39	27.5±4.7	12.3±1.8	0.818±0.112	18.9±0.9	51.3±1.5
	5	515±37	26.6±2.1	14.5±0.8	0.741±0.016	18.7±0.8	48.9±1.3
	B	521±31	23.5±3.5	14.5±1.1	0.733±0.046	18.9±0.3	49.3±0.8
Viseu	T	567±38	45.0±2.5	12.6±1.5	0.664±0.056	17.9±1.2	51.2±1.0
	65	551±47	37.0±2.7	13.5±0.3	0.764±0.045	17.3±1.3	49.5±1.8
	35	510±34	29.7±3.5	13.2±1.1	0.752±0.069	19.3±1.4	51.8±1.6
	15	517±50	27.2±4.4	13.6±1.3	0.725±0.008	20.1±1.1	51.8±2.8
	5	531±22	26.6±2.8	13.7±1.3	0.751±0.051	19.3±2.1	49.7±2.0
	B	543±30	25.0±6.9	14.8±1.9	0.748±0.047	19.3±1.3	49.3±1.6

Variation of biometric characteristics

In average we can see that when the fibre length increases the fibre width decreases. In fact the lower vales of fibre length where observed for the lower and higher height levels. In the higher height levels it is caused by a great amount of juvenile wood, and in the lower height levels it is caused by the presence of reaction wood as an effect of tree weight.

For Ovar Stand we don't observe that tendency. In that case to a higher fibre length correspond a height fibre width maybe caused by good condition in the stand to tree growth when is compared with the other stands. In fact for the same DBH the average total height values was superior for that trees caused for a higher tree growth.

Principal components Analysis

The result off analysis is presented in Figure 2, where each point represents the mean of a given property. The first component explains 35.32%, the second explains 24.3% and the third explains 15.6% of the total variation.

Factor 1, which defines the first component of pulp properties, includes a series of properties, which are significantly correlated amongst themselves: ISO brightness, pulp yield and kappa number (that in inverse order

from the others). In fact, all the first variables are related with chemical composition of the wood. In Factor 2, was explained by the wood density and no other variables are well correlated with him.
Factor 3 was responsible for the fibre characteristics (fibre width and length) and they are correlated in inverse order. Similar results from fibre characteristics are reported by Santos *et al*. (2005) for *A. dealbata*, *A. melanoxylon* and *E. globulus* pulps.

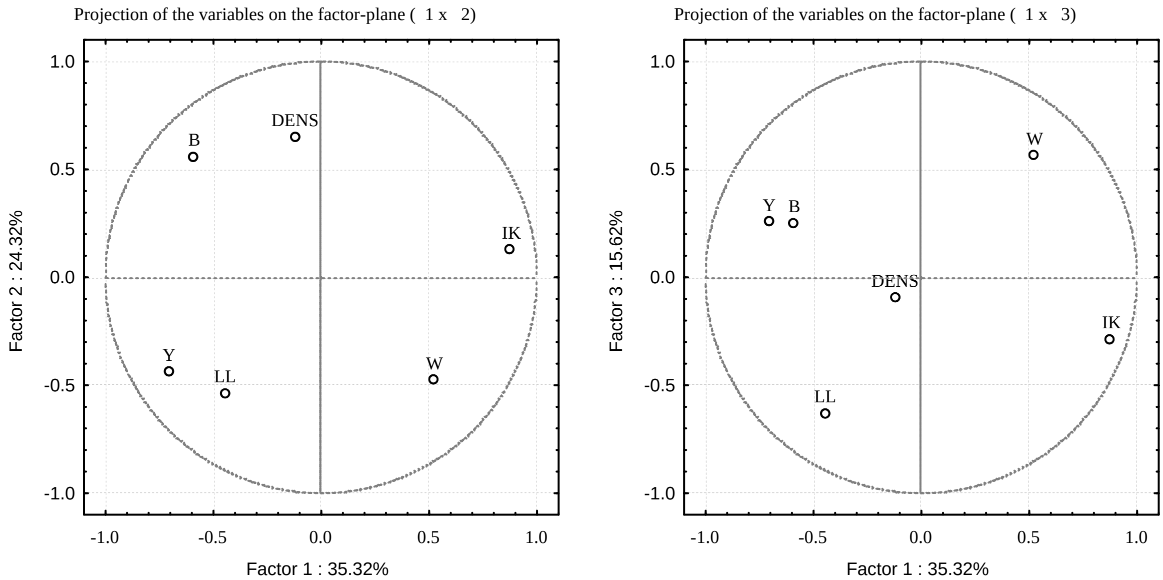

Figure 2. Relative distribution of pulp characteristics according to the factors resulting form Principal components analysis, for all variables.

Paavilainen (2002) studied the influence of morphological characteristics of the fibres in paper properties and in fact they are well correlated and justify the majority of the variability of paper properties for a given pulping process, but the cooking conditions can also have a marked influence on the papermaking potential of the pulp fibres.
The behaviour of the different stands comparatively for studied parameters seems not very different. In fact that seems to have a trend for a separation for a group of some stands like Viseu or Ponte de Lima, but there are a great variability observed already in the variance analysis.

IV. CONCLUSIONS

The overall mean basic density measured at 5% height level (near breast height level) was 516 kg/m^3 with a 34 kg/m^3 standard deviation. The within tree axial variation of density was of small magnitude, but showing higher values at the stem base and top. Site had no influence on the basic density of the trees.
The wood density is well correlated with the brightness of the pulps.

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